The Effect of Instructions and Context-Related Information about Limitations of Conditionally Automated Vehicles on Situation Awareness

Quentin Meteier
HumanTech Institute,
HES-SO//University of Applied Sciences and Arts Western Switzerland
Fribourg, Switzerland
quentin.meteier@hes-so.ch

Marine Capallera
HumanTech Institute,
HES-SO//University of Applied Sciences and Arts Western Switzerland
Fribourg, Switzerland
marine.capallera@hes-so.ch

Emmanuel de Salis
Haute Ecole Arc Ingénierie, HES-SO
Saint-Imier, Switzerland
emmanuel.desalis@he-arc.ch

Andreas Sonderegger
Department of Psychology, University of Fribourg
Fribourg, Switzerland
andreas.sonderegger@unifr.ch

Leonardo Angelini
HumanTech Institute,
HES-SO//University of Applied Sciences and Arts Western Switzerland
Fribourg, Switzerland
leonardo.angelini@hes-so.ch

Stefano Carrino
Haute Ecole Arc Ingénierie, HES-SO
Neuchâtel, Switzerland
stefano.carrino@hes-so.ch

Omar Abou Khaled
HumanTech Institute,
HES-SO//University of Applied Sciences and Arts Western Switzerland
Fribourg, Switzerland
omar.aboukhaled@hes-so.ch

Elena Mugellini
HumanTech Institute,
HES-SO//University of Applied Sciences and Arts Western Switzerland
Fribourg, Switzerland
elena.mugellini@hes-so.ch

ABSTRACT

In conditionally automated driving, drivers do not have to constantly monitor their vehicle but they must be able to take over control when necessary. In this paper, we assess the impact of instructions about limitations of automation and the presentation of context-related information through a mobile application on the situation awareness and takeover performance of drivers. We conducted an experiment with 80 participants in a fixed-base driving simulator. Participants drove for an hour in conditional automation while performing secondary tasks on a tablet. Besides, they had to react to five different takeover requests. In addition to the assessment of behavioral data (e.g. quality of takeover), participants rated their situation awareness after each takeover situation. Instructions and context-related information on limitations combined showed encouraging results to raise awareness and improve takeover performance.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

AutomotiveUI '20, September 21–22, 2020, Virtual Event, DC, USA

© 2020 Copyright held by the owner/author(s). Publication rights licensed to ACM.

ACM ISBN 978-1-4503-8065-2/20/09…$15.00
https://doi.org/10.1145/3409120.3410649

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; *User studies*; Usability testing; • **Applied computing** → *Psychology*.

KEYWORDS

automated driving, instructions, limitations, mobile application, situation awareness, takeover performance

ACM Reference Format:

Quentin Meteier, Marine Capallera, Emmanuel de Salis, Andreas Sonderegger, Leonardo Angelini, Stefano Carrino, Omar Abou Khaled, and Elena Mugellini. 2020. The Effect of Instructions and Context-Related Information about Limitations of Conditionally Automated Vehicles on Situation Awareness. In *12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '20), September 21–22, 2020, Virtual Event, DC, USA*. ACM, New York, NY, USA, 11 pages. https://doi.org/10.1145/3409120.3410649

1 INTRODUCTION

In Conditionally Automated Driving (CAD) [16], vehicles can perform all the driving tasks. However, technology is not infallible and the automation may still encounter some situations it cannot handle. In this case, the vehicle may require drivers to take over control. In CAD, drivers do not have to constantly monitor their vehicle, but they must still be able to resume manual driving if necessary. However, as drivers are allowed to perform a secondary task in CAD, the takeover action might be linked with a higher cognitive workload and thus, could lead to potentially dangerous situations [8]. In addition, monitoring tasks could be annoying and may induce drowsiness if there is no associated secondary task [31]. Therefore, it is important to keep the drivers "in-the-loop" during CAD maintaining their Situation Awareness (SA) and reducing their cognitive workload during takeover phases by accompanying them in the supervision task.

To support drivers' supervision task, we investigate how to maintain their SA, which is their ability to perceive elements, to comprehend their meaning and to project actions according to these information [9]. For this, we use a mobile application designed for this purpose. The role of this application is to convey context-related information to drivers about their surroundings such as the presence of obstacles, the state of the vehicle and its sensors. Moreover, Endsley [9] argued that drivers' expertise in systems limitations impact their SA. Thus, we seek to determine whether knowing the factors limiting the proper functioning of automated vehicle would make the supervision task more efficient as well a effective takeover.

2 RELATED WORK

2.1 Situation Awareness

The concept of Situation Awareness has been largely studied in the aviation domain [9] but the investigation of SA is also relevant in the automotive field [10]. Drivers have to maintain knowledge about navigation, environment and interaction, spatial orientation and vehicle status. SA is divided into 3 cognitive levels: Perception, Comprehension and Projection [9]. SA should be assessed for a precise element at a specific time and cannot be measured directly. That is why researchers focus on measuring indirectly the awareness at a given point of time through different graphic interfaces [28], [26].

Currently, the most common way to assess SA is the use of freeze-probe techniques such as SAGAT (Situation Awareness Global Assessment Technique) or subjective post-trial questionnaires like SART (Situation Awareness Rating Technique) [29]. The second one is more simplistic and describes driver's SA using 3 dimensions: demands on attentional resources, the supply of attentional resources, and understanding of the situation. In their study, Van den Beukel et al. used both SAGAT to obtain an objective measure of SA and SART to assess a more the subjective SA from the driver [30].

2.2 Limitations of automation

Today, cars are delivered with assistive technology but there is still a research gap in this domain. Because automation cannot handle all the situations encountered, it is necessary to identify the factors limiting the operation of conditionally automated vehicles.

Martí et al. [23] realized a review of sensor technologies in automated driving. In a part of the study, they described the characteristics (type of information detected, ranges, robustness…) of different sensors used for perception such as vision, radar or LiDAR. For example, weather and other environmental factors can degrade the proper functioning of the sensors.

Capallera and colleagues realized an analysis of factors limiting the proper functioning of partially automated vehicles [6], corresponding to level 2 cars [16]. Their taxonomy composed of six macro-categories (External Human Factor, Lane, Road, Environment, Obstacles, Vehicle Alteration) led us to depict the status of ADAS and individuate the critical factors that may lead to potentially hazardous situations. In addition, the authors provided insights on which limitations should be better conveyed through interfaces.

Studies on conditionally automated vehicles (Level 3, c.f. [16]) were carried out through the disengagement reports of automated cars by Favarò et al. [11, 12]. The main limitations concern the driver. The majority of transitions from CAD to manual driving were made by the driver due to a sense of discomfort or lack of confidence in the system. This analysis demonstrates the need to consider the driver and the implications of these limitations in the design and conception of human-vehicle interactions.

Moreover, recent empirical studies have investigated how the ADAS presentation to drivers can impact their trust, acceptance and awareness of the system. Bloemacher et al. [3] indicate that a wrong preliminary description of the system leads to a poor SA. Thus, it is important to provide a correct description of driving automation systems through the owner manual or an interactive tutorial as proven by Forster et al. [13].

2.3 Interfaces increasing SA

Results of the previous studies show that numerous limitations are often mentioned in manuals but rarely notified to the driver [6], causing a lack of SA. Currently, interfaces increasing driver's SA are mainly visual or auditory and located on the windshield or the central console [22, 33]. Miller et al. [25] use a personal device but only in takeover situations and do not transmit information about its environment to the driver. Because drivers may be able to perform a secondary task, it would be interesting to use their device to transmit information about their environment while performing a Non-Driving Related Task (NDRT). To do this, Capallera et al. [7] have developed an application for tablet that transmits limitations that could affect the proper functioning of automated vehicles. The mobile application was tested in a CAD simulator. They found that participants were able to identify some of the critical factors proposed. Overall, participants also appreciated the ease of understanding of the information transmitted by the application. However, the authors didn't study the impact of the application on driver's SA and takeover quality. This critical aspect will be studied in this paper.

2.4 Takeover Performance

Takeover performance is also used as an evaluation for SA, with stronger SA delivering faster and higher takeover quality [18]. In this study, we will look at three mains metrics for takeover quality and rapidity:

- Reaction time (RT), which is the difference between the takeover request (TOR) and the effective time of takeover, either by braking or steering. Lower RT indicates quicker takeover. However, RT alone is not a sufficient metric when

NDRTs are performed since the quality of the takeover can significantly vary with constant RT [34].
- Maximum steering wheel angle (MaxSWA) is the maximum angle attained on the steering wheel during the whole takeover process, from effective takeover until resuming the CAD mode. Higher MaxSWA indicates lower takeover quality [4].
- Maximum braking (MaxBraking) is the maximum pressure on the brake pedal attained during the takeover process. The braking behavior can be seen as an indicator of the awareness of the driver, whether it is a reactive (lower SA) or intended (higher SA) brake [21].

3 CURRENT STUDY

These study objectives are to describe the impact of:

a) Instructions about the limitations of automated vehicles

b) Context-related information displayed via a mobile application on the situation awareness and takeover performance of drivers. According to [18], we expect that changes in drivers' SA will be reflected in the takeover quality (eg. higher SA leads to better takeover quality). SA is measured by means of the SART and an open-ended question asking about the cause of the TOR. In addition, takeover quality is evaluated using the indicators presented above. Based on the related work, we formulate the following hypotheses:

- (H1) Participants who receive a description about limitations of automation before the experiment have a higher SA in every takeover situation. Thus, we also expect that takeover quality will be better [3, 13].
- (H2) Participants for whom context-related information are displayed on a tablet during the experiment have higher SA in every takeover situation. Thus, we also expect that takeover quality is better [27].
- (H3) Participants who both receive a general description and context-related information about limitations of automation have highest SA, followed by participants receiving either description of limitations or context-related information while participants who do not receive any information about the limitations score lowest for SA. Thus, we also expect a similar effect pattern for takeover quality.
- (H4) Participants who perform a visual NDRT before the TOR have a lower SA and show worse takeover quality than participants performing an auditory NDRT [32].
- (H5) As completion of the visual NDRT requires participants to monitor the tablet on which context-related information is displayed, we assume that the context-related information has a stronger influence on SA (and improve the takeover quality) compared to performing the auditory task.

4 METHOD

4.1 Participants and experimental design

80 participants (54 females) were recruited for this study. Participants were recruited among students and the general population. The age of the participants ranged from 19 to 66 years old (M = 23.94 years old; SD = 8.25 years old). On average, they reported driving 6312 km per year (SD = 14 415 km) and have held a driving license for about 5 years and a half (SD = 8.10 years). The only criterion for participating in this experiment was to be in possession of a valid driver's license. Students received course credit for their participation. All the research and measurements followed the tenets of the Helsinki agreement and written informed consent was obtained from all participants.

The design of the experiment included two between-subjects factors (instructions and mobile application) as well as one within-subjects factor (task modality) while task difficulty was varied systematically but not considered as factor in this work. The first between-subjects factor was the instructions given to the participants about the limitations of conditionally automated vehicles, referred to as *Instructions* later in the article. The second one was the context-related information provided to the driver while the car was driving in conditional automation. These additional information were presented via a mobile application displayed in split-screen mode on a tablet (Fig. 1). Drivers received information with regard to the environment of the car in real-time: the current weather (sunny vs. cloudy vs. rainy), the shape of the road, the state of the lane markings and obstacles around the car (icons and proximity sensors). We call this factor *Mobile Application* later in the article.

In brief, this gave us four experimental groups of 20 people:

- Group **IA** was informed about limitations of conditionally automated vehicles and received context-related information
- Group **I** was informed about limitations of conditionally automated vehicles
- Group **A** received context-related information
- Group **N** did not receive any information

Throughout the driving session, participants had to perform a succession of cognitive NDRTs (N-back task) that were either visual or auditory. We call this within-subjects factor *Task Modality* in the article. The order of the tasks was randomized throughout the experiment but controlled (Latin Square design) before the takeover situations.

In addition, the participants had to react to five different takeover situations. The order of apparition and the location of takeover situations in the scenario was the same for all participants. Each takeover was requested due to a limitation of automation. These situations depicted five of the six categories of the taxonomy proposed by Capallera et al. [6], which were :

1. A slope with no visibility behind the hill (Category Road)
2. Damaged and vanishing lane markings until they were fully erased (Category Lanes)
3. A massive rock on the right lane (Category Obstacle)
4. Heavy rain (Category Environment)
5. A deer standing on the right side of the road and then crossing over (Category External Human Factor)

In the later, we will respectively call these situations **Slope**, **Lanes**, **Rock**, **Rain** and **Deer**.

4.2 Material

The experiment was conducted on a fixed-base simulator, containing two adjacent car seats and a Logitech G27 steering wheel with a pedal set. The simulated environment was back-projected on a large screen with a projector (model Epsilon EH-TW3200). Two

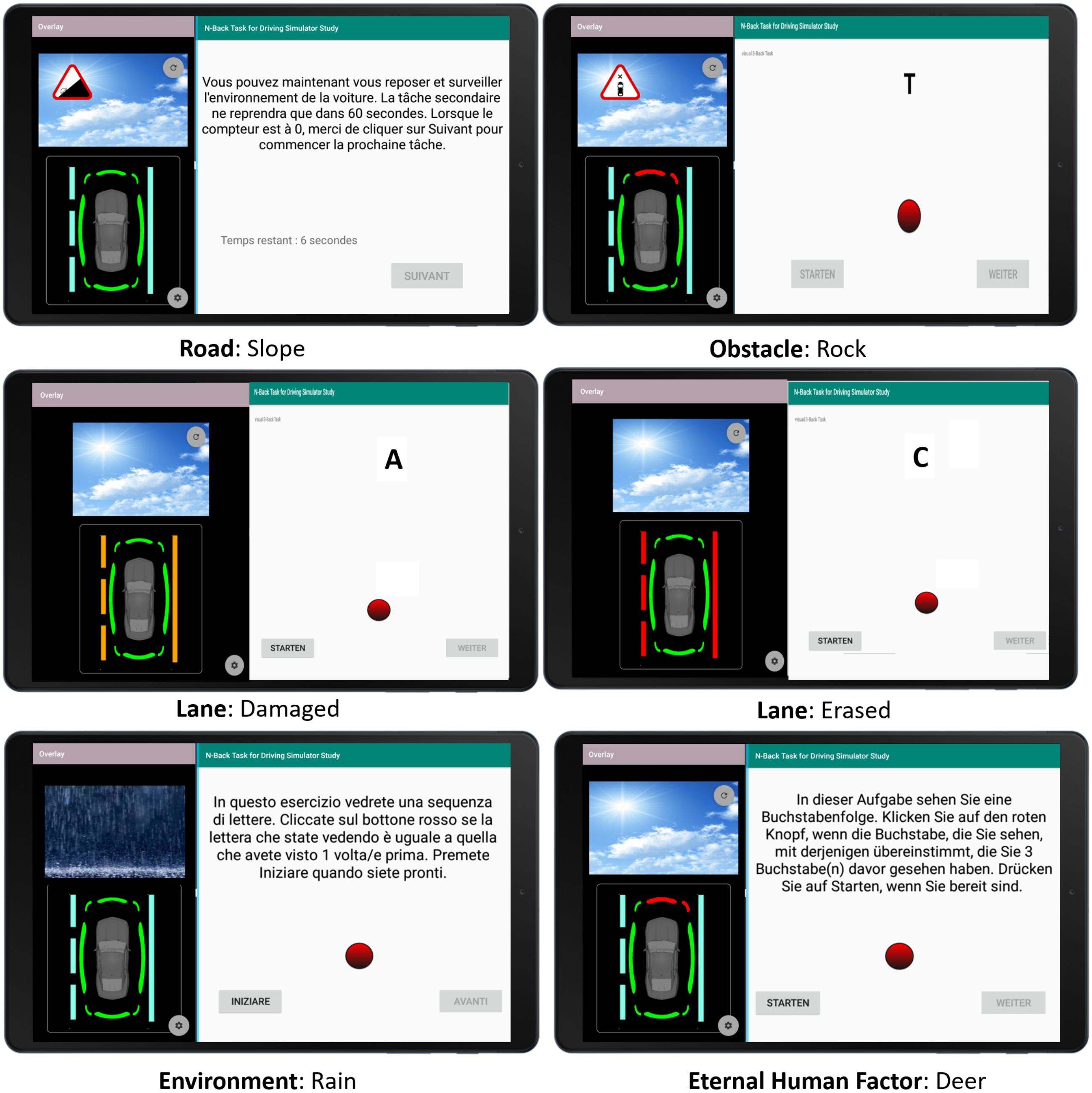

Figure 1: The context-related information displayed on a mobile application in split-screen mode with the secondary task.

speakers were set up behind the seats in order to immerse the driver in the simulated environment. This whole setup was located in a cabin-like room with low ambient illumination. To take over control of the car during the experiment, the drivers could either steer the wheel (more than 26 degrees), brake or press a button of the steering to disengage the autopilot and regain full control of the car.

For the driving simulation, the software used was GENIVI [1]. The scenario modelled the Yosemite National Park (USA) and proposed a CAD mode. This scenario had been modified to add the takeover situations mentioned in the experimental design.

All participants used a Samsung Galaxy Tab A (10") to perform the NDRTs and answer midterm questionnaires. An Android mobile application was developed to administer the N-back task. Each sequence contained 28 letters, with four letters considered as targets (correct answers). For the visual task, each letter was displayed for 2.5 seconds, with an inter-stimulus of 500 milliseconds. In the same way, audio files recorded by experimenters were played for the auditory task. For half of the participants, the additional mobile application was displayed in split-screen mode.

4.3 Measures and instruments

SA of drivers was assessed using a 3D-SART and an open question asking for the cause of the TOR. Post-trial questionnaires were used because we preferred not to freeze the simulation while collecting physiological data. These data were collected but are not analysed in this paper. Out of simplicity, the three dimensions of SART will be named Demand (D), Supply (S) and Understanding (U). SA is calculated using the following formula SA = U-(D-S). Each SART item was rated on a 7-point scale: 1 (Low) and 7 (High).

Takeover quality was evaluated from the driving data. The metrics used were the drivers' RT, MaxSWA and MaxBraking. In this study, MaxBraking corresponds to the maximum value for the position of the brake pedal during the takeover. We computed these three metrics because the experiment combines situations where the driver can either avoid an obstacle or brake to complete stop. All the driving data were recorded throughout the driving sessions.

Half of the participants answered to the User Experience Questionnaire Short version (UEQ-S) [19] in order to assess the pragmatic and hedonic quality of the mobile application, according to its attractiveness, perspicuity, efficiency, dependability, stimulation and novelty.

4.4 Procedure

After initial instructions about the experiment, the participants filled in a questionnaire on a tablet containing socio-demographic questions as well as questions about their driving habits. For participants who received *Instructions* (IA or I), they had to familiarize themselves with two printed documents presenting the 26 limitations of automated vehicles. These limitations were presented in the form of taxonomy with categories and also illustrated a situation involving all categories (printed from [6]). Once they had assimilated the limitations, they were asked to take a seat in the driving simulator. The experiment was divided into three distinct periods that are detailed below. Oral instructions were given by the experimenter before each period to ensure that the participants understood the experimental procedure.

During the first period, the participants were asked to monitor the environment of the vehicle while driving in conditional automation for five minutes. The subjects were told that no takeover could be requested during this period.

During the second period, the participants could familiarize with the takeover process as well as with the driving functions of the simulator. The subjects were reminded that they were driving a conditionally automated vehicle. The meaning of icons showing the state of the autopilot on the dashboard was explained to the drivers. The experimenter also instructed on how taking over control of the car. The participants got about one minute to drive manually to get used to the simulator. After that, all the participants received three "fake" takeover requests triggered by the experimenter. There was no critical situation and this method was only used to show them what a TOR looked like. Each TOR was announced by a red icon on the dashboard and a chime. Once participants were familiar with the takeover process, they could drive manually to the end of that five-minute period.

The third period consisted of the main driving session that lasted about an hour. The participants were given a tablet with a mobile application displayed on it, which led them through the whole main driving session and presented sequentially the instructions, the secondary tasks and the questionnaires. Depending on their condition (A or IA), the *Mobile Application* tested as part of this study was displayed in split-screen mode on the tablet. After explanations about the information presented on the *Mobile Application*, participants were informed to focus on the NDRT while driving. No specific instruction regarding visual attention were provided for the auditory NDRT. In case of a TOR, participants were instructed to react accordingly and drive the car manually until the critical situation was over. Once they had estimated that the situation was safe again, they could activate the autopilot again. If they forgot to reactivate, the researcher reminded them. The main driving session consisted of five blocks, each containing one takeover situation and three epochs of secondary task. Each epoch of secondary task lasted 90 seconds, followed by 60 seconds of rest. After the secondary task in which the takeover occurred, the subjects were presented the open question for the cause of TOR and the SART on the tablet. They had to answer the questions based on their evaluation of the previous critical situation. At the end of the session, participants were asked to stop the car and leave the simulator to fill in the last part of the questionnaire. Participants for whom the *Mobile Application* was displayed throughout the experiment (A or IA condition) were also asked to respond to the UEQ-S in order to rate their user experience with this application. Finally, participants were thanked and discharged.

4.5 Statistical analysis

To investigate the effect of *Instructions*, *Mobile Application*, *Task Modality*, as well as interaction effects (*Instructions x Mobile Application* and *Task Modality x Mobile Application*), the 2-factorial logistic regression with post-hoc chi-square tests were chosen for the cause of takeover and a 2-factorial ANOVA was performed on the other dependant variables (SART scores and takeover indicators). A statistical analysis was performed for each dependent variable and each takeover situation (**Slope**, **Lanes**, **Rock**, **Rain** and **Deer**).

Some participants had to be excluded from the statistical analysis. Several times, the *Mobile Application* crashed before the takeover. For two participants, this was the case during the **Slope** situation, for five participants during the **Lanes** situations and for one participant during the **Rain** situation. In addition, due to slow reading speed of some participants, TOR appeared during the resting period between two NDRT epochs instead of the NDRT epoch. This was the case for 18 participants in the **Slope** situation, four in the **Lanes** situation, and four in the **Rain** situation. The respective participants were removed from the statistical analysis when we analysed influence of *Mobile Application* or *Task Modality* on dependent variables. For indicators of takeover quality, participants were excluded if they already had the control of the car when the TOR appeared or if they did not take over control of the car.

5 RESULTS

5.1 User understanding of TOR causes

For each takeover situation, an open question was asked to verify if participants understood why a takeover was requested by the car. The cause of TOR seemed to be obvious for the **Rock**, the **Rain** and the **Deer** situations, because independently from their experimental condition, almost all participants had the correct answers (respectively 78 out of 80, 77 out of 79 and 78 out of 80). However, there was a higher proportion of wrong answers for the **Slope** and **Lanes** situations, so we focused the analysis on these two situations.

The factorial logistic regression showed a significant effect of *Instructions* on the number of correct answers for the **Lanes** situation ($X^2(1) = 3.875$, $p < .05$). An additional chi-square test showed that the manipulation group had higher proportion of correct answers (59.5%) compared to the control group (36.8%; $X^2(1) = 3.842$, $p < .05$). The statistical analysis for the **Slope** situation did not show significant results. Besides, the *Mobile Application* did not show any significant effect on the number of correct answers for both situations.

Also, the statistical analysis showed a significant effect of the interaction of *Instructions* and *Mobile Application* for the **Slope** situation ($X^2(3) = 7.129$, $p < .05$). The proportion of correct answers was statistically lower (75%) in the control group (N) than the group that received additional *Instructions* and had the *Mobile Application* (IA) throughout the driving session (100%; $X^2(1) = 5.182$, $p < .05$). The statistical analysis did not show a significant interaction effect of both factors for the **Lanes** situation. Still, a chi-square test showed the proportion of correct answers was statistically lower (30%) in the control group (N) compared to the manipulation (IA) group (64.7%; $X^2(1) = 4.457$, $p < .05$).

5.2 SART

The following results present the effect of the between-subjects factors on the three components of the SART (Demand, Supply and Understanding) and the composite SART score (SA). Table 1 shows significance levels of each factor on SA for each takeover situation. Means are reported in the text when the significance level is reached.

5.2.1 Effect of Instructions. The statistical analysis showed a significant effect of the *Instructions* on SA during the **Slope** situation ($F(1,74) = 6.946$, $p < .05$, $\mu^2 = .086$). The group that received *Instructions* on limitations indicated to have a higher SA when the car came across the **Slope** (M = 22.736, SD = .982) compared to the control group (M = 19.125, SD = 0.956). Also, results showed a significant effect of *Instructions* on participants' SA during the **Rock** situation ($F(1,76) = 5.590$, $p < .05$, $\mu^2 = .069$). Participants in the *Instructions* group indicated to have a higher SA (M = 22.625, SD = 1.101) compared to the control group (M = 18.900, SD = 1.101). An additional ANOVA on the SART components revealed that this significant difference came from the Demand component ($F(1,76) = 7.163$, $p<.05$, $\mu^2 = .086$). The manipulation group indicated that the situation asked for a lower demand on attentional resources (M = 7.400, SD = .694) compared to the control group (M = 10.025, SD = .694). Table 1 also shows a strong trend in the SA score for the **Lanes** situation (higher SA for the *Instructions* group).

5.2.2 Effect of Mobile Application. A significant effect of the *Mobile Application* on self-reported SA was found for the **Deer** situation ($F(1,76) = 4.048$, $p < .05$, $\mu^2 = .051$). When the car approached the deer standing by the side of the road, participants who had the context-related information displayed on the *Mobile Application* indicated to have lower SA (M = 16.675, SD = 1.063) compared to the control group (M = 19.700, SD = 1.063). An ANOVA on SART components revealed a significant difference on Understanding ratings ($F(1,76) = 4.407$, $p<.05$, $\mu^2 = .055$), showing a poorer understanding for the manipulation group (M = 11.550, SD = .615) compared to the control group (M = 13.375, SD = .633).

5.2.3 Effect of Instructions x Mobile Application and post-hoc tests. Besides, we investigated the double interaction of the *Instructions* and the *Mobile Application* on SART ratings. The statistical analysis did not show any significant results for any takeover situation. To validate or refute (H3), post-hoc t-tests showed that SA was higher for the manipulation group (IA; M = 24.94, SD = 6.036)) than the control group (N; M = 19.80, SD = 5.908)) for the **Lanes** situation ($t(35) = 2.612$, $p < .05$). The **Slope** situation showed the same pattern and was marginally significant ($t(36) = 1.995$, $p = .054$). However, the SA was lower for the IA group (M = 14.30, SD = 6.325) compared to the N group (M = 19.40, SD = 6.707) during the **Deer** situation ($t(38) = -2.474$, $p < .05$).

5.2.4 Effect of Task Modality and Task Modality x Mobile Application. The statistical analysis showed no effect of the *Task Modality* alone on self-reported SA. However, the data analysis revealed a significant effect of the double interaction *Task Modality* x *Mobile Application* on SA for the **Lanes** ($F(1,54) = 6.187$, $p < .05$, $\mu^2 = .103$), the **Rain** ($F(1,59) = 7.773$, $p < .05$, $\mu^2 = .116$) and the **Deer** ($F(1,60) = 4.299$, $p < .05$, $\mu^2 = .067$) situations. Means and interaction effects for these three takeover situations are presented on Figure 2. Table 1 also shows that the effect in the **Rock** situation was marginally significant. Additional ANOVAs on components of SART revealed a significant effect of *Task Modality* x *Mobile Application* on the Understanding score for the **Rock** situation ($F(1,56) = 4.965$, $p<.05$, $\mu^2 = .081$) and on the Supply score for the **Rain** ($F(1,59) = 4.137$, $p < .05$, $\mu^2 = .066$) and the **Deer** ($F(1,60) = 5.385$, $p < .05$, $\mu^2 = .082$) situations.

5.3 Takeover quality

As for SA ratings, Table 1 shows significance levels for the effect of each factor on the three takeover indicators (RT, MaxSWA, MaxBraking). Means are reported in the text when the significance level is reached.

5.3.1 Effect of Instructions and Mobile Application. For the **Deer** situation, a significant effect of *Instructions* was found on RT ($F(1,67) = 4.067$, $p < .05$, $\mu^2 = .057$). The group of participants who received *Instructions* on limitations had a lower RT when the car approached the deer (M = 2.135, SD = 0.291) than the control group (M = 2.972,

Table 1: Significance levels for the effect of Instructions (I), Mobile Application (MA), Instructions x Mobile Application (I x MA), Task Modality (TM) and Task Modality x Mobile Application (TM x MA) on measures of SA and takeover performance (RT, MaxSWA (MS) and MaxBraking (MB)). Bold values indicate p < .10 while asterisk indicate p < .05.

	Slope				Lanes				Rock				Rain				Deer			
	SA	RT	MS	MB	SA	RT	MS	MB	SA	RT	MS	MB	SA	RT	MS	MB	SA	RT	MS	MB
I	**.01***	.88	.30	.53	**.06**	.69	.28	.36	**.02***	.79	.73	.55	.17	.35	**.06**	.77	.17	**.05***	.83	.20
MA	.74	.39	.92	**.06**	.13	.22	.41	.40	.79	.64	.12	.40	.55	.65	.77	.39	**.05**	.23	**.09**	.53
I x MA	.71	.73	.53	.37	.47	.06	.83	**.01***	.76	.33	.28	.32	.34	.78	.38	.21	**.08**	.84	.77	.45
TM	.45	.28	.45	.92	.12	.80	.61	.47	.78	.43	.15	.55	.92	.30	.44	.99	.44	.44	.92	.78
TM x MA	.68	.17	.46	.18	**.02***	.44	.18	.67	**.06**	.92	.87	**.05**	**.01***	.89	**.05**	.93	**.04***	.98	.66	.90

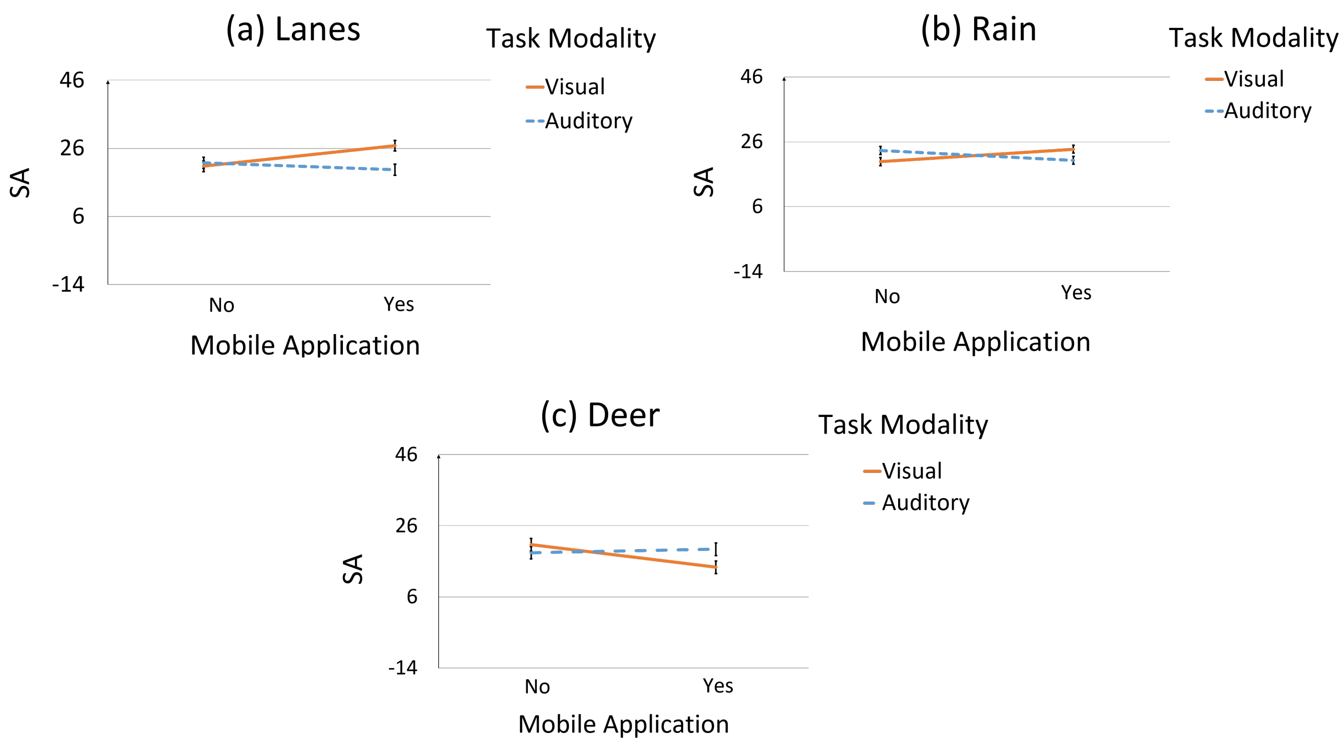

Figure 2: Interaction effect of *Task Modality* and *Mobile Application* on SA during the Lanes situation (a), the Rain situation (b), and the Deer situation (c).

SD = 0.295). For the **Lanes** situation, a significant effect of *Instructions x Mobile Application* was found on MaxBraking (F(1,62) = 6.888, p < .05, μ^2= .100). On one hand, for participants who had the *Mobile Application*, those who did not received *Instructions* braked stronger (M = 31.00, SD = 35.61) compared to those who received them (M = 16.98, SD = 34.35). Lower MaxBraking values indicate lighter braking action. On the other hand, for participants who did not have the *Mobile Application*, those who did not received *Instructions* braked lighter (M = 16.32, SD = 28.34) compared to those who received them (M = 45.50, SD = 34.39).

Table 1 also shows tendencies that were not statistically significant but which are interesting to be discussed. For the **Slope** situation, a strong tendency (but not significant) was found on MaxBraking, showing a lower value of the maximum position of brake pedal for the group with the *Mobile Application* (M = 25.746, SD = 6.175) than the group without the application (M = 42.127, SD = 5.995). For the **Deer** situation, a tendency (but not significant) of the effect of the *Mobile Application* was found on MaxSWA. The MaxSWA was lower for participants who experimented the additional *Mobile Application* on the tablet (M = 24.472, SD = 10.622) compared to the others (M = 50.739, SD = 10.777).

5.3.2 Effect of Task Modality and Task Modality x Mobile Application. No significant effect of the *Task Modality* alone was found on takeover indicators for each situation. However, Table 1 shows that the effect of *Task Modality x Mobile Application* on MaxBraking for the **Rock** situation and MaxSWA for the **Rain** situation was marginally significant.

5.4 User Experience - Mobile Application

Half of the participants (N = 40) filled in the UEQ-S to assess the mobile application. A toolkit to analyse the results is provided by the questionnaire authors [19]. We interpreted the means of the scales related to pragmatic quality and hedonic quality. The range of the scales is between -3 (horribly bad) and +3 (extremely good). Overall, the application was assessed just above average and both pragmatic and hedonic qualities had a positive mean value. According to the pragmatic part, the application was in order easy (1.8), supportive and efficient (1.3) and a little bit clear (1.2). Concerning the hedonic part, the application was a little bit leading edge and interesting (0.6), inventive (0.5) and not really exciting (0.1). Thus, the mobile application had good pragmatic (1.388) quality, which is the first purpose of a prototype and the main objective of this study, but poor hedonic (0.450) quality, which might be improved in future versions of the application.

6 DISCUSSION

6.1 Hypotheses testing

The first goal of the study was to investigate the effect of *Instructions* on drivers' SA. ***The first hypothesis (H1) is partly validated.*** Drivers who received *Instructions* before the experiment showed to better identify the cause of TOR in the **Lanes** situation. It seems that receiving instructions before the experiment helped the drivers to face such a confusing situation. Indeed, it might have been hard to understand that the actual cause of TOR was the erased lanes because some participants indicated that the TOR was triggered because of an intersection or a sharp turn. *Instructions* could help people to better identify the TOR cause, understand the critical situation, react to it accordingly and decrease the chance of accidents. Besides, participants who received *Instructions* perceived to have a higher SA (based on SART ratings) for the **Slope** and the **Rock** situations, which came from a lower demand on attentional resources. The same assertion can also be made for the **Lanes** situation since the results of self-reported SA from SART are consistent with results for understanding the cause of TOR. Even though the effect of *Instructions* was not consistent on SA across situations, it showed promising findings for raising perceived awareness in three situations that might not be known as dangerous for automation. Concerning the takeover performance, participants who received *Instructions* were quicker to take over control when approaching the **Deer**. In other words, subjects familiar with the limitations of automated vehicles disengaged faster the autopilot, probably because they knew that a mobile obstacle could be difficult for the conditionally automated vehicle to handle. In general, providing instructions before driving had a beneficial effect on awareness and comprehension abilities of participants in three out of five situations. In this study, the training process on system limitations was short and we did not check if the participants understood and assimilated system limitations. It could be interesting to measure the impact of training time about automated cars limitations. For example, we could compare SA of drivers who received long-term and short-term training on automated cars limitations before the experiment.

Another main purpose of the study was to evaluate the impact of conveying context-related information through the *Mobile Application* on drivers' SA in various takeover situations. ***The hypothesis (H2) has not been confirmed***. Results showed that the context-related information alone did not help participants to better identify the cause of takeover and increase their SA. However, participants who received additional information through the application indicated to have a lower SA for the **Deer** situation, due to lower understanding according to SART ratings. This shows results opposite to those expected. This suggests that context-related information might be beneficial for SA only in straight-forward and static situations that do not involve TOR due to moving obstacles and dynamic factors outside the car (Category External human factor, [6]). Another explanation for the undesired effect of the application is that it uses the same icon to alert about the **Deer** and the **Rock** situation. Therefore, it might have been confusing for participants who had the application when the car approached the deer. This could explain the lower score in the Understanding component of SART. Therefore, a more explicit icon for the takeover situations caused by moving entities (person or animal) should be used.

Besides, providing context-related information showed encouraging results concerning the takeover quality. Participants braked softer for the **Slope** situation, which was the expected behaviour in such a situation. Since there was no traffic, this situation required only to brake softly to take over control of the car. We also observed an interesting result for one takeover due to the presence of an obstacle on the lane (**Deer**). Participants with the application regained control with lower MaxSWA value, indicating a better reaction for taking over control using the steering wheel. However, subjects did not get higher RT with the *Mobile Application* across all situations, meaning that it is not a hindrance to RT. It supports the fact that using such an IHM to maintain awareness is realistic. The first purpose of providing context-related information was to raise participants' awareness. However, even if self-reported awareness using SART did not increase, the takeover quality seems to be improved in some situations.

The third hypothesis (H3) is validated for specific conditions. Statistical analysis showed a significant effect for the interaction of the two factors on the proportion of correct answers for the cause of takeovers for **Slope** and **Lanes** situations. The control group (N) had more difficulties to identify the cause of takeover in these situations compared to the manipulation group that received both *Instructions* before and real-time information during the drive (IA). Ratings of SA for these two situations were consistent with results for cause of TOR. It shows that the two ways of conveying information about limitations should be combined in order to help the drivers to correctly identify the cause of critical situations requiring a takeover. In this case, this is true for situations related to the characteristics of the road conditions, in particular, when the cause of takeover is confusing as it was the case in the **Lanes** situation. As a result, participants who received the context-related information on the application in addition to their initial knowledge on system limitations knew that there was a TOR because of the erased lanes and not because of the sharp turn. Results also shows that the additional *Instructions* given to participants who had the mobile application helped them to react accordingly by braking lightly when approaching the erased lanes. However, the instructions given to participants with the application had a negative effect on their behaviour because it led them to brake harder. This shows the positive aspect of providing both instructions and context-related information about vehicle limitations, and not just general information like in owner manuals.

Another goal of the study was to analyse the effect of the *Task Modality* performed by drivers on their SA. Results showed that for the same physical disposition (tablet in hands), there was no difference in self-reported SA and takeover performance whether the task was auditory or visual. ***Thus, (H4) is refuted.***

Finally, we verified if the context-related information presented on the tablet were beneficial only for a specific modality of NDRT (visual or auditory). According to the SART results (Fig. 2), the context-related information displayed on the *Mobile Application* showed to be beneficial for participants' SA performing a visual NDRT before the takeover in the **Lanes** and the **Rain** situations, while the SA decreased for participants performing an auditory NDRT. Therefore, the use of the application on a handheld tablet should be used to prevent the drivers from limitations coming on the car's route, specifically when they are performing a visual task. This suggests that this way of conveying information about the environmental conditions and lane markings quality is efficient for raising drivers' SA while performing a visual NDRT on the same device where the information message is conveyed. However, the takeover situation with the deer showed that providing additional information while performing the visual task resulted in lower SA. The nature of the factor causing the takeover (e.g. salient and focal information) could explain why SA is not necessarily raised while interacting with the mobile application and performing a visual task [15]. Because of this negative effect, we may consider the use of another modality in order to convey information to the driver in such situation (i.e. presence of a mobile obstacle while performing a visual task). For example, it would be possible to use vibration into the driver seat to notify the presence of the obstacle around the vehicle [2, 5, 14]. ***Therefore, (H5) is validated for the Lanes and Rain situations but refuted for the Deer.*** However, due to the relatively small sample size and the qualitative nature of the SA measure, this conclusion must be interpreted with caution and requires further empirical evaluation. These results highlight the importance to know the modality of NDRT performed by the driver at any moment if we want to maintain or even increase their awareness by providing context-related information through in-car interfaces.

6.2 Lesson learned, limitations, and future research

To summarize the findings of this study, providing instructions on system limitations seems to be necessary for drivers to understand the causes of the TORs. It highlights the importance of preventing drivers about limitations before using these vehicles. This was already advised to increase trust and acceptance [13], using tutorials or owners manuals. However, since few people read the owner manuals of their cars [24], it would be a good idea to find an interactive way for conveying such information to the drivers. Besides, the mobile application tested in this study seems to be a good complementary tool to give context-related information. A solution could be to combine the two factors (instructions + application) by making the mobile application interactive. For instance, if new information or an icon would appear on the application to warn for a limitation, the driver would have the possibility to click on the element and get additional details about this limitation (e.g., in a popup). Also, this could potentially increase drivers' user experience with the application because it would give them the possibility to be proactive.

Besides, results showed that providing context-related information through a mobile application is not always beneficial, especially for dangerous situations with moving obstacles such as a deer. Results also suggest taking into account the type of NDRT (and the driver's state) when conveying additional information useful for drivers' SA. Based on experimental results, a rule-based system could choose to display the information on the application or in another location (for instance on the HUD) to maintain an optimal level of drivers' SA. In addition to the choice of location, the model could convey the information through another modality such as voice interaction or seat vibration. For further research, we are planning to explore these modalities to increase SA. The mobile application tested in this study will be redesigned to become more interactive. In addition, further UX-design iterations will be conducted in order to assure that information provided by the mobile application is intuitive and easy to understand. It cannot be excluded that some of the nil effects reported above are a consequence of the novel and non-standardised design of signs and visualisations used in the mobile application. We will also conduct other experiments to manipulate the SA, using other interaction modalities and driving scenarios with takeover situations.

Several limitations need to be taken into consideration when interpreting the presented findings. First, the study is based on a student sample. Although driving experience of participants was assessed, the sample is rather young and not representative for the distribution of driving experience and age of the general population. In addition, sample size is limited for several statistical analyses due to a considerable number of excluded participants as a consequence of technical issues. For these specific cases it cannot be excluded that, despite a conducted analysis for outliers, random results might have occurred. This is why these results need to be confirmed by further research. Furthermore, data have been obtained in a static driving simulator. Despite the highly immersive nature of the installation, driving behavior in a simulator might be different compared to a real environment [17, 20]. In this context, great care was taken to simulate as realistic a driving scenario as possible. Therefore it was necessary to keep the order of the takeover situations constant (each participant always drove the same route and received a TOR at the identical place). This is why it was not possible to present the TOR in a randomized order, which might have led to order effects that could not be controlled for. An additional source of uncontrolled variance might be found in the instructions for the auditory NDRT. As participants were simply instructed to concentrate on the NDRT and oculomotor behavior was not assessed, we do not know where participants looked at while completing the auditory NDRTs.

7 CONCLUSION

In this study about conditionally automated driving, we investigated the effect of providing instructions on system limitations before the driving session and real-time context-related information on a tablet while driving. 80 participants in a fixed-base driving simulator drove in conditional automation while performing a succession of NDRTs on a handheld tablet. They also had to react to five takeover requests caused by various factors. The drivers' SA was manipulated using printed materials, a mobile application and various hazardous situations in the driving scenario. The participants indicated that the mobile application was convenient and suggested that the design could be improved to be more appealing. The effect of instructions on system limitations showed encouraging results to increase awareness for three out of five situations. The effect of context-related information on limitations alone did not increase awareness but slightly improved the takeover performance. However, the context-related information increased drivers' SA when performing a visual secondary task in two situations but decreased their SA in another situation. Therefore, it suggests that the modality of the secondary task (visual vs. auditory) needs to be taken into account when conveying context-related information to raise awareness of drivers in real-time with a mobile application.

ACKNOWLEDGMENTS

This work has been supported by Hasler Foundation in the framework of AdVitam project. The authors would like to thank all the persons who contributed to this paper.

REFERENCES

[1] 2018. GENIVI Vehicle Simulator. https://at.projects.genivi.org/wiki/display/PROJ/GENIVI+Vehicle+Simulator

[2] David Beattie, Lynne Baillie, Martin Halvey, and Rod Mccall. 2014. What's Around the Corner? Enhancing Driver Awareness in Autonomous Vehicles via In-Vehicle Spatial Auditory Displays. *Proceedings of the NordiCHI 2014: The 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*. https://doi.org/10.1145/2639189.2641206

[3] Katja Blömacher, Gerhard Nöcker, and Markus Huff. 2018. The role of system description for conditionally automated vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour* 54 (Apr 2018), 159–170. https://doi.org/10.1016/j.trf.2018.01.010

[4] M. Bueno, E. Dogan, F. Hadj Selem, E. Monacelli, S. Boverie, and A. Guillaume. 2016. How different mental workload levels affect the take-over control after automated driving. In *2016 IEEE 19th International Conference on Intelligent Transportation Systems (ITSC)*. 2040–2045.

[5] Marine Capallera, Peïo Barbé-Labarthe, Leonardo Angelini, Omar Abou Khaled, and Elena Mugellini. 2019. Convey Situation Awareness in Conditionally Automated Driving with a Haptic Seat. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications: Adjunct Proceedings* (Utrecht, Netherlands) *(AutomotiveUI '19)*. Association for Computing Machinery, New York, NY, USA, 161–165. https://doi.org/10.1145/3349263.3351309

[6] Marine Capallera, Quentin Meteier, Emmanuel de Salis, Leonardo Angelini, Stefano Carrino, Omar Abou Khaled, and Elena Mugellini. 2019. Owner Manuals Review and Taxonomy of ADAS Limitations in Partially Automated Vehicles. In *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '19)*. Association for Computing Machinery, 156–164. https://doi.org/10.1145/3342197.3344530

[7] Marine Capallera, Quentin Meteier, Emmanuel de Salis, Leonardo Angelini, Stefano Carrino, Omar Abou Khaled, and Elena Mugellini. 2019. Secondary task and situation awareness, a mobile application for semi-autonomous vehicle. In *Proceedings of the 31st Conference on l'Interaction Homme-Machine (IHM '19)*. Association for Computing Machinery, 1–10. https://doi.org/10.1145/3366550.3372258

[8] Ebru Dogan, Mohamed-Cherif Rahal, Renaud Deborne, Patricia Delhomme, Andras Kemeny, and Jérôme Perrin. 2017. Transition of control in a partially automated vehicle: Effects of anticipation and non-driving-related task involvement. *Transportation Research Part F: Traffic Psychology and Behaviour* 46 (Apr 2017), 205–215. https://doi.org/10.1016/j.trf.2017.01.012

[9] Mica R. Endsley. 1995. Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 37, 1 (Mar 1995), 32–64. https://doi.org/10.1518/001872095779049543

[10] Mica R. Endsley. 2019. Situation Awareness in Future Autonomous Vehicles: Beware of the Unexpected. In *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018)*, Sebastiano Bagnara, Riccardo Tartaglia, Sara Albolino, Thomas Alexander, and Yushi Fujita (Eds.). Springer International Publishing, Cham, 303–309.

[11] Francesca Favarò, Sky Eurich, and Nazanin Nader. 2017. Autonomous vehicles' disengagements: Trends, triggers, and regulatory limitations. *Accident; analysis and prevention* 110 (11 2017), 136–148. https://doi.org/10.1016/j.aap.2017.11.001

[12] Francesca M. Favarò, Nazanin Nader, Sky O. Eurich, Michelle Tripp, and Naresh Varadaraju. 2017. Examining accident reports involving autonomous vehicles in California. *PLOS ONE* 12, 9 (09 2017), 1–20. https://doi.org/10.1371/journal.pone.0184952

[13] Yannick Forster, Sebastian Hergeth, Frederik Naujoks, Josef Krems, and Andreas Keinath. 2019. User Education in Automated Driving: Owner's Manual and Interactive Tutorial Support Mental Model Formation and Human-Automation Interaction. *Information* 10, 4 (Apr 2019), 143. https://doi.org/10.3390/info10040143

[14] Thomas Grah, Felix Epp, Martin Wuchse, Alexander Meschtscherjakov, Frank Gabler, Arnd Steinmetz, and Manfred Tscheligi. 2015. Dorsal Haptic Display: A Shape-changing Car Seat for Sensory Augmentation of Rear Obstacles. In *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '15)*. ACM, New York, NY, USA, 305–312. https://doi.org/10.1145/2799250.2799281

[15] William J Horrey, Christopher D Wickens, and Kyle P Consalus. 2006. Modeling drivers' visual attention allocation while interacting with in-vehicle technologies. *Journal of Experimental Psychology: Applied* 12, 2 (2006), 67.

[16] SAE International. 2018. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.

[17] Michel J. Johnson, Tammem Chahal, Arne Stinchcombe, Nadia Mullen, Bruce Weaver, and Michel Bédard. 2011. Physiological responses to simulated and on-road driving. *International Journal of Psychophysiology* 81, 3 (2011), 203 – 208. https://doi.org/10.1016/j.ijpsycho.2011.06.012 PROCEEDINGS OF THE 15TH WORLD CONGRESS OF PSYCHOPHYSIOLOGY of the International Organization of Psychophysiology (I.O.P.) Budapest, Hungary September 1-4, 2010.

[18] HyunSuk Kim, Woojin Kim, Jungsook Kim, Seung-Jun Lee, and DaeSub Yoon. 2019. A study on the Effects of Providing Situation Awareness Information for the Control Authority Transition of Automated Vehicle. In *2019 International Conference on Information and Communication Technology Convergence (ICTC)*. 1394–1396. https://doi.org/10.1109/ICTC46691.2019.8939867

[19] Bettina Laugwitz, Theo Held, and Martin Schrepp. 2008. Construction and Evaluation of a User Experience Questionnaire. In *HCI and Usability for Education and Work (Lecture Notes in Computer Science)*, Andreas Holzinger (Ed.). Springer, 63–76. https://doi.org/10.1007/978-3-540-89350-9_6

[20] Henry L. Lew, John H. Poole, Eun Ha Lee, David L. Jaffe, Hsiu-Chen Huang, and Edward Brodd. 2005. Predictive validity of driving-simulator assessments following traumatic brain injury: a preliminary study. *Brain Injury* 19, 3 (2005), 177–188. https://doi.org/10.1080/02699050400017171 arXiv:https://doi.org/10.1080/02699050400017171 PMID: 15832892.

[21] N. Li, T. Misu, and F. Tao. 2017. Understand driver awareness through brake behavior analysis: Reactive versus intended hard brake. In *2017 IEEE Intelligent Vehicles Symposium (IV)*. 1523–1528.

[22] Andreas Löcken, Heiko Müller, Wilko Heuten, and Susanne Boll. 2013. AmbiCar: Towards an in-vehicle ambient light display.

[23] Enrique Marti, Miguel Angel de Miguel, Fernando Garcia, and Joshue Perez. 2019. A Review of Sensor Technologies for Perception in Automated Driving. *IEEE Intelligent Transportation Systems Magazine* 11, 4 (2019), 94–108. https://doi.org/10.1109/MITS.2019.2907630

[24] Brad Mehlenbacher, Michael Wogalter, and Kenneth Laughery. 2002. On the Reading of Product Owner's Manuals: Perceptions and Product Complexity. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 46 (09 2002). https://doi.org/10.1177/154193120204600610

[25] David Miller, Annabel Sun, Mishel Johns, Hillary Ive, David Sirkin, Sudipto Aich, and Wendy Ju. 2016. Distraction Becomes Engagement in Automated Driving:. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Dec 2016). https://doi.org/10.1177/1541931215591362

[26] J.C. Scholtz, B. Antonishek, and J.D. Young. 2005. Implementation of a situation awareness assessment tool for evaluation of human-robot interfaces. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans* 35, 4 (Jul 2005), 450–459. https://doi.org/10.1109/TSMCA.2005.850589

[27] Bobbie D. Seppelt and John D. Lee. 2007. Making adaptive cruise control (ACC) limits visible. *International Journal of Human-Computer Studies* 65, 3 (Mar 2007), 192–205. https://doi.org/10.1016/j.ijhcs.2006.10.001

[28] David Sirkin, Nikolas Martelaro, Mishel Johns, and Wendy Ju. 2017. Toward Measurement of Situation Awareness in Autonomous Vehicles. In *Proceedings*

of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). Association for Computing Machinery, 405–415. https://doi.org/10.1145/3025453.3025822

[29] Taylor. 2019. Situation Awareness Rating Technique (SART).

[30] Arie P. van den Beukel and Mascha C. van der Voort. 2017. How to assess driver's interaction with partially automated driving systems - A framework for early concept assessment. *Applied Ergonomics* 59 (Mar 2017), 302–312. https://doi.org/10.1016/j.apergo.2016.09.005 Patent Number: A.

[31] Tobias Vogelpohl, Matthias Kühn, Thomas Hummel, and Mark Vollrath. 2019. Asleep at the automated wheel-Sleepiness and fatigue during highly automated driving. *Accident; Analysis and Prevention* 126 (May 2019), 70–84. https://doi.org/10.1016/j.aap.2018.03.013

[32] Bernhard Wandtner, Nadja Schömig, and Gerald Schmidt. 2018. Effects of Non-Driving Related Task Modalities on Takeover Performance in Highly Automated Driving. *Human Factors* 60, 6 (2018), 870–881. https://doi.org/10.1177/0018720818768199

[33] MinJuan Wang, Sus Lundgren Lyckvi, Chenhui Chen, Palle Dahlstedt, and Fang Chen. 2017. Using Advisory 3D Sound Cues to Improve Drivers' Performance and Situation Awareness. (2017), 2814–2825. https://doi.org/10.1145/3025453.3025634

[34] Kathrin Zeeb, Axel Buchner, and Michael Schrauf. 2016. Is take-over time all that matters? The impact of visual-cognitive load on driver take-over quality after conditionally automated driving. *Accident; analysis and prevention* 92 (04 2016), 230–239. https://doi.org/10.1016/j.aap.2016.04.002